7

AUDIOLOGY AND PSYCHOACOUSTICS

Audiology is the science of hearing — the term derives from Latin "audīre", "to hear" and from Greek "-logia", "the study or science of". Hearing is not just a mechanical phenomenon , but also a mental process. Psychoacoustics is concerned with the human perception

Improved acoustic measurement has been fundamental to advances in the speech and hearing sciences. Audiology, the branch of science that studies human hearing, balance and related disorders, has been markedly dependent on technological innovations such as the vacuum tube amplifiers, transistors and digital technology. Accurate characterization of the electroacoustic performance of hearing aids is basic to understanding the relation between human hearing and hearing aid design.

Improved methods of signal processing have developed modern hearing aids that include advanced methods of amplitude compression, feedback cancellation, beamforming microphone arrays for increased directionality, and other methods of speech enhancement.
Speech is the most important communication mechanism for mankind. As a result, a human being's hearing reaches its highest sensitivity at frequencies between 200Hz-8kHz. This bandwidth is typically the bandwidth in which normal phonetics takes place. Definition of the speech signal is fundamental to understanding the relation between speech perception and the acoustics of speech.

Audiology

Audiology contains a diverse collection of scientific, technical, clinical and rehabilitational disciplines, which together represent the complex whole. In addition to medicine and physiology, engineering and physics are basic areas which play an important role. Psychology is another area of increasing importance, both with regard to the interplay between auditory function and cognitive abilities and in terms of providing a basic understanding of the handicap experienced by hearing loss and how this can be ameliorated.
People who work in the field of audiology come from a wide range of disciplines and levels of educational achievement. Among the relevant subjects studied at school, college or university are: physics, psychology, medicine, physiology, engineering, speech sciences, mathematics, electronics, biology, laboratory sciences and physiological measurement, psycho-acoustics, biochemistry and acoustics. Audiological engineering may be considered an interdisciplinary field between electrical and biomedical engineering**.**
Audiological acoustics is concerned with both psychoacoustics and physiological acoustics. This includes the signal processing in the human auditory system, the perceptual consequences of hearing

impairment, models of auditory and audiovisual processing and perception, applications of auditory models in hearing instruments, as well as sound and speech perception.
The applications of this field are concerned with issues of both human comfort, such as sound quality, and human safety, e.g. control and reduction of sound and vibration exposure. Audiology and psychoacoustics are growing fields and can provide a career with good prospects in a practical field with a satisfying mix of clinical, technical, and scientific and rehabilitation practices.

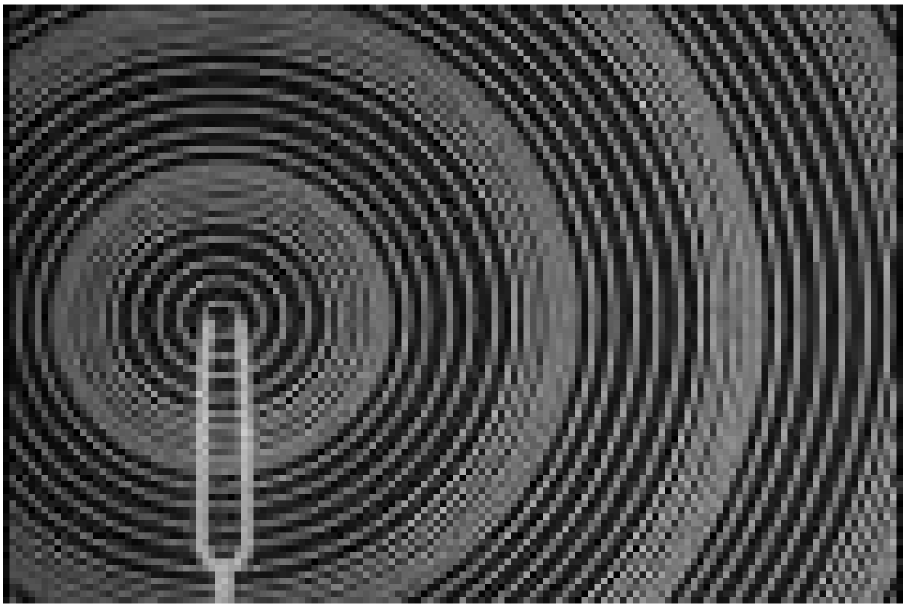
Physiological Acoustics

Hearing is mostly evaluated by behavioural testing, i.e. observing and recording a person's response to a sound. However, hearing can also be tested without the client having to respond. In this physiological testing special equipment is used to measure hearing by measuring the way the ear and brain respond to sound.
Physiological acoustics is the study of specific responses that may occur in the ear or elsewhere along the central auditory pathways, following presentation of an appropriate stimulus at any level of the auditory system. Such responses may be recorded with the aid of various techniques which may be mechanical, electrical, optical, and so forth. The specific stimulus for the ear is acoustic energy. Experimentally, signals with well-defined parameters are used. The approach employed by physiological acoustics is therefore purely analytical. This is in contrast to the holistic approach employed by psychoacoustics, which lends itself well to experiments on human subjects.

Psychoacoustics

The human perception of sound is a very complex process and highly non-linear. It calls for acoustical descriptors different from those used in normal "linear" sound work.
Psychoacoustics is the study of the human subjective perception of physical sound. Whereas physical sound can be measured the same by different individuals, the perception of sound will vary from one individual to another. Alternatively psychoacoustics can be described as the study of how people react to sound, hearing and perception. Hearing is not a purely mechanical phenomenon of wave propagation, but is also a sensory and perceptual event. When a person hears a sound, that sound reaches the ear as a sound wave travelling through the air, but within the ear it is transformed into neural action potentials. These nerve pulses then travel to the brain where they are perceived. For example, the physical energy of a sound is perceived as loudness, or the physical frequency of a sound is perceived as pitch.
When working with problems in acoustics, such as audio processing, it is often advantageous to take into account not just the physics of the environment, but also the fact that both the ear and the brain are involved in a person's listening experience.
Psychoacoustics is an important and multifaceted discipline that is still developing. At universities and professional schools, psychoacoustics is most often taught as part of some broader education or training program, most often medical studies (audiology), architecture (noise effects, sound insulation or damping), or language studies (speech perception), but other combinations including electroacoustics occur as well.
Psychoacoustics is presently applied within many fields like software development, where developers map proven and experimental mathematical patterns, or design of audio systems for accurate reproduction of music in theatres and homes. Yet another application is in the design of small or lower-quality loudspeakers, which use the phenomenon of missing fundamentals to give the effect of low frequency bass notes that the system, due to frequency limitations, cannot actually reproduce.

Sound waves are acoustic waves, with no electrical component. They are simply vibrations, variations in physical pressure, in the air.

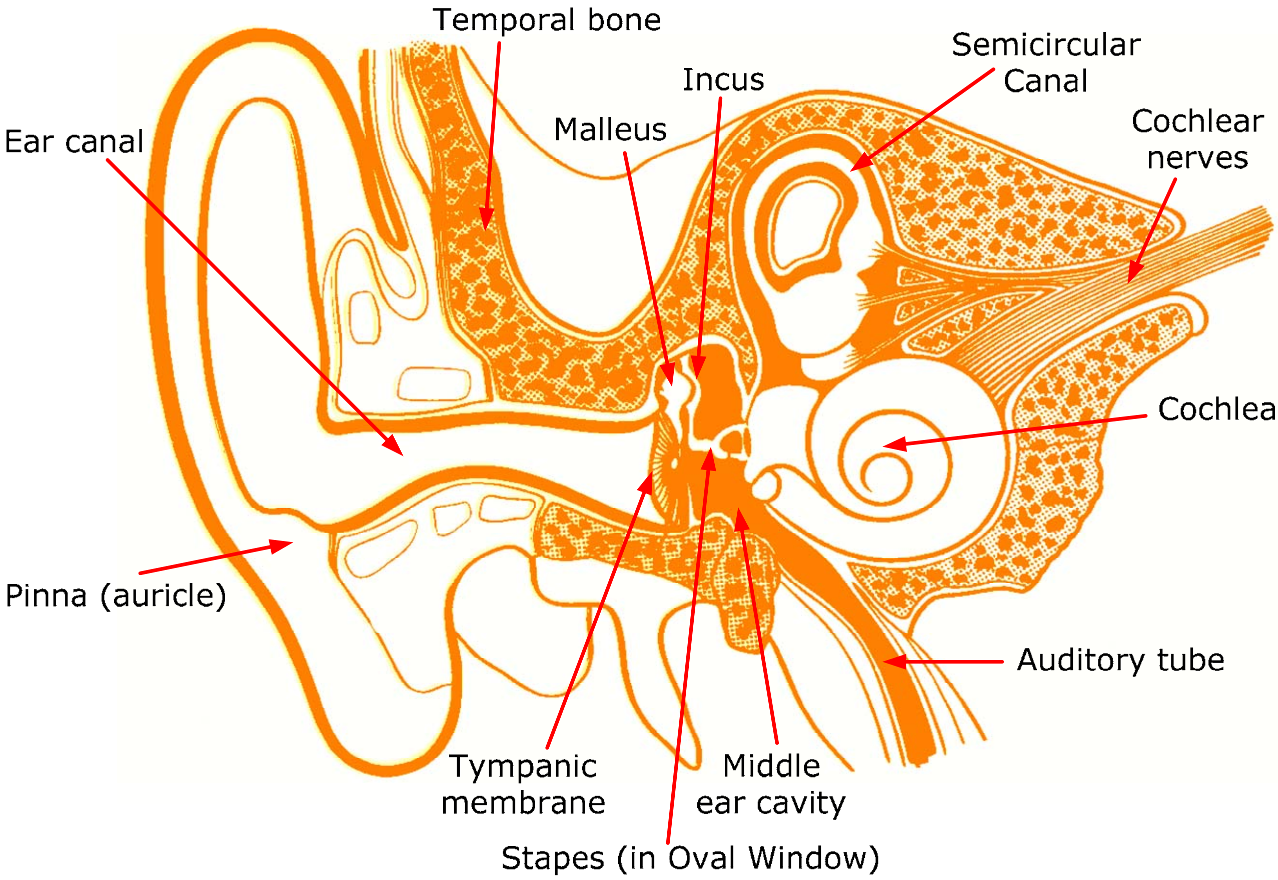


Technical Psychoacoustics

Subjective testing with actual human beings is often replaced by technical psychoacoustic solutions, quantitative modelling based on an understanding of relationship between sound stimuli and auditory perception in terms of hearing sensations.
Applications of technical psychoacoustics are important in the development of new digital audio technologies. Audio codecs, devices or programs capable of encoding and/or decoding a digital data stream or signal, are essential components in new multimedia and broadcast services. They depend on the characteristics of the auditory system to compress audio information for efficient transmission and storage at low bit rates. Also, objective quality measurement schemes, which depend heavily on psychoacoustic knowledge, have been developed to simulate subjective ratings of audio quality.

The Hearing Mechanism

Hearing is necessary for many desirable things: for communication, the enjoyment of music, and to locate sound sources. However, it is also the means by which humans receive undesirable noise. The reception and analysis of sound is a complicated process and the ear itself is a complex instrument capa-

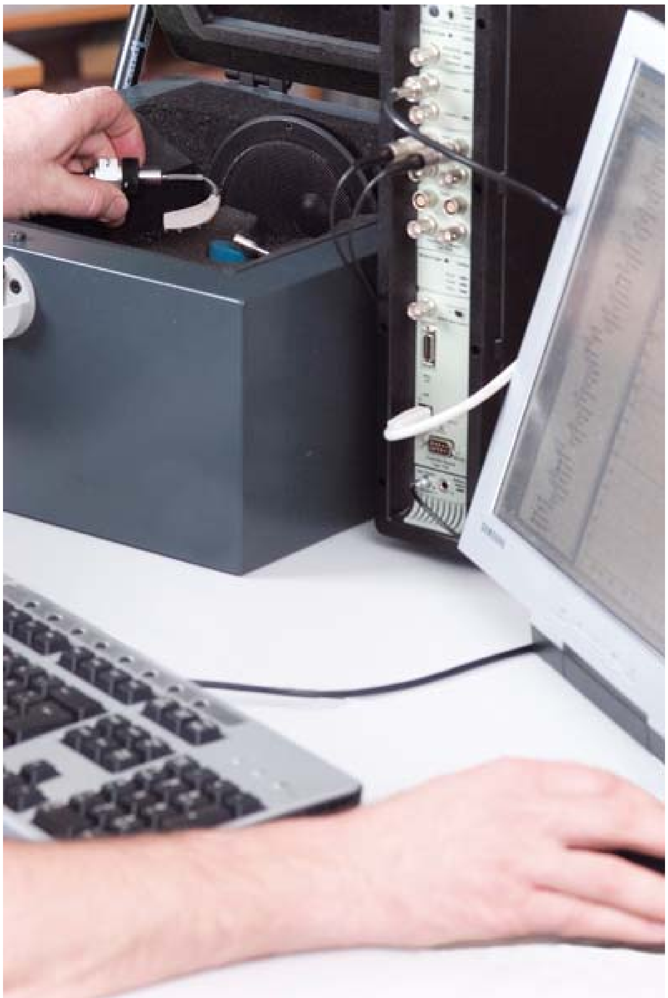


The human ear is a complex organ. It receives sound in the form of sound waves that strike the eardrum. These waves move from the eardrum through the bones of the middle ear to the cochlea, a spiral-shaped organ filled with fluid. The vibration sets the fluid in motion and sensory cells along the cochlea's basic membrane send messages of the sound to the brain. The brain is capable of distinguishing many distinct sounds.

ble of excellent discrimination over a wide range of frequencies and sound intensities.
The human ear consists of three main parts: outer ear, middle ear and the inner ear. The outer and middle ear collects the airborne sound waves and passes them to the liquid-filled inner ear. This acts as a transducer, converting mechanical vibration signals into neural impulses, with which acoustical information is transferred to the brain.
The inner ear consists of two separate systems, the semi-circular canals which are concerned primarily with balance, and the cochlea which is concerned with hearing. The liquid-filled cavity of the cochlea is divided into two longitudinal canals by the basilar membrane, which extends along the cochlea's entire length except for a small gap called the helicotrema at the far end.
When the stirrup, responding to an acoustic stimulus, moves the oval window, the resultant fluid disturbance passes along the upper canal (scala vestibule), past the helicotrema, into the lower canal (scala tympani) and ultimately the oval window deflects to accommodate it. By this system of canals, levers, membranes and hair cells, the ear is able to detect sounds over enormous ranges of frequency and intensity. The highest frequency of sound that the healthy human ear can hear is 1000 times the frequency of the lowest, and the loudest can have a sound pressure level one million times that of the most quiet, detectable to the ear.
As the fluid disturbance passes through the canals, it causes different parts of the basilar membrane to vibrate. There are thousands of very sensitive hair cells on the upper part of the basilar membrane and these register the vibration and transform it into nerve impulses which are ultimately transmitted to the brain through the nerves fibres.

Bone conduction

There is another route by which sound can reach the inner ear: by conduction through the bones of the skull. When the handle of a vibrating tuning fork is placed on a bony prominence such as the forehead or mastoid process behind the ear, its note is clearly audible. Similarly, the ticking of a watch held between the teeth can be distinctly heard. When the external canals are closed with the fingers, the sound becomes louder, indicating that it is not entering the ear by the usual channel. Instead, it is producing vibrations of the skull that are passed on to the inner ear, either directly or indirectly, through the bone. The bone conduction vibrator is an electromechanical transducer that produces the sensation of hearing via the bones of the head. It converts electric signals into mechanical vibrations which transmit sounds. Converted vibration signals go through the temple to the head bone



Hearing aid testing performed in an anechoic box.

and stimulate the auditory nerve via bone vibrations. This process allows sounds to bypass the eardrum.
Bone Conduction devices are not placed on the ear to detect sounds. Instead they are placed over the temple which transmits sounds directly into the inner ear. Such devices can be placed as an extension of eyeglass arms.

Noise Exposure
Exposure to noise constitutes a health risk. Noise exposure can induce hearing impairment, hypertension and ischemic heart disease, annoyance, sleep disturbance, increased workplace accident rates and decreased school performance. Hearing loss can be immediate with extreme sound levels, but, in general, the problem is exposure to noise over time.
Most public health impacts of noise were already identified in the 1960s and noise abatement is less of a scientific but primarily a policy problem. A high priority study subject is the effects of noise on children, including cognitive effects and their reversibility. Noise exposure is on the increase, especially in the general living environment.
The essential issue in fighting noise induced health risks is the assessment of noise exposure. Effective noise control measures have a positive effect on people. They increase a sense of well being and privacy which in turn results in a greater acceptance of the work environment.
Noise emission values are increasingly becoming the subject of regulations for a safer and healthier working place and for the protection of the environment. Sound power has become the preferred quantity to describe noise emissions as it is independent of the particular circumstances of the measuring environment.
Sound Power can be determined according to three main methods:

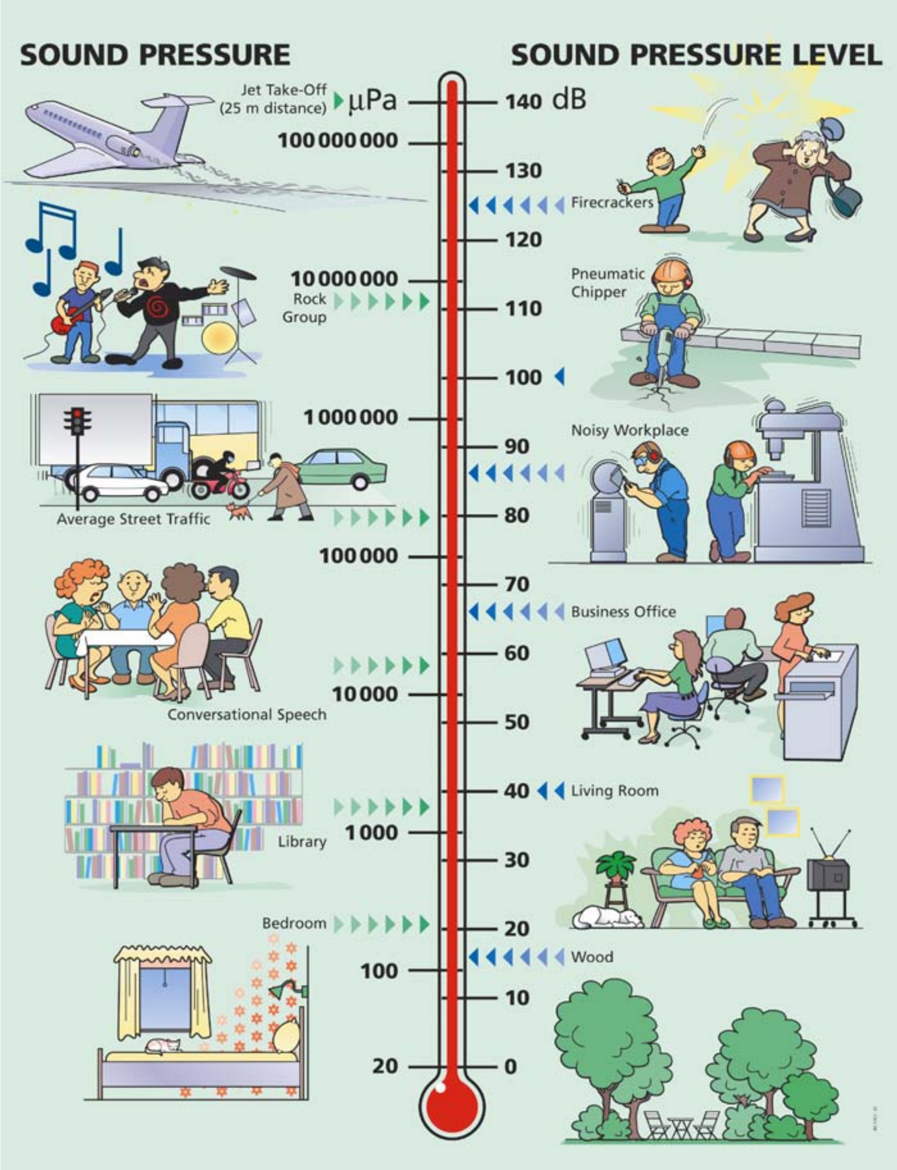
1. Measure the sound pressure due to the source in a free (or essentially free) sound field, and then determine its sound power from the sound pressure measurements.
2. As 1, but in a diffuse sound field.
3. Direct measurements of sound intensity in any sound field to determine the sound power of the source.

The pressure-based methods are most often used for production audits and high-volume testing (with specific standards for information technology equipment), while the intensity-based methods are generally used for engineering and in-situ measurements.
The essential issue in fighting noise-induced hearing loss is the assessment of noise exposure. A noise dose meter is typically used to measure the amount of noise an individual is exposed to throughout the working day. The meter is worn with the microphone fastened close to the ear and measures the sound pressure level and calculates the so-called noise "dose" received by the individual during the day. The noise dose is expressed as the equivalent average sound level for an 8-hour period (reference duration) and this level must be below the limit (or Criterion Level) specified in the relevant occupational health regulation (often an 85 dB limit is used). The noise dose may also be expressed as a percentage of the maximum allowed.

Vibration Exposure
Human vibration is defined as the effect of mechanical vibration in the environment on the human body. During our normal daily lives we are exposed to various sources of vibration, for example, in buses, trains and cars. Many people are also exposed to other vibrations during their working day, for example, vibrations produced by hand-tools, machinery or heavy vehicles. Human response to vibration differs according to the intensity and frequency range of the vibration, time of exposure and the point of contact.
There are two main types of human vibration – whole-body vibration and hand-arm vibration.
Whole-body vibration is transmitted to the body as a whole, mainly through the supporting surface (that is, feet, buttocks, back, etc.). Prolonged exposure to whole-body vibration can either cause permanent physical damage or disturb the nervous system.
Hand-arm vibration is experienced through the hand and arm. Daily exposure to hand-arm vibration over a number of years can cause permanent physical damage, usually resulting in what is commonly known as "white-finger syndrome", or it can damage the joints and muscles of the wrist and/or elbow.
A lot of research and studies have been made to evaluate the effect of over-exposure to human vibration, especially in the working environment. The results have been used to establish international standards that allow human exposure to vibration to be evaluated. The standards involve measurements of whole-body vibration and hand-arm

vibration using instruments that fulfil the requirements of the standards.
The vibrational characteristics are described by frequency, amplitude and acceleration. As with noise, logarithms are used to indicate the magnitude of vibrations. The units are the same decibels (dB). This is by Weber-Fechner's Law that states "the sensation is proportional to the logarithm of the stimulus."

Human Modelling
Human ear simulators are primarily intended for frequency response, sensitivity and distortion measurements on earphones coupled to the ear by ear inserts such as tubes, ear moulds or ear tips, for example, as used in hearing aids and operator headsets. The main ear canal volume is of a similar shape and volume to that of the actual human ear and provides similar acoustic impedance to the insert earphone being tested.
Other simulators are mannequins with built-in ear and mouth simulators which provide realistic reproduction of the acoustic properties of an average adult human head and torso. They are used to perform in-situ electro-acoustic tests on audio-devices like telephone handsets, headsets, audio conference devices, microphones, headphones, hearing aids and hearing protectors.
More advanced simulators have been designed for the calibration of bone conduction hearing aids and bone vibrators used in audiometry. They simulate the mechanical characteristics of the human mastoid, the portion of the temporal bone, which encloses the middle ear and forms the outer wall of the inner ear. They provide a mechanical simulation of the human head, incorporating a built-in force transducer to monitor the output of the device to be calibrated.



Hearing Level (dBHL)
The hearing level can be defined as the measure of the status of hearing as read directly on the hearing loss scale of an audiometer. It is described in decibels as a deviation from a standard value for zero on the audiometer. Hearing loss is measured in decibels hearing level (dBHL). A person who can hear sounds across a range of frequencies at 0 to 20dB is considered to have normal hearing. The level at which a person cannot hear a sound of a certain frequency is known as their threshold. Hearing of speech is considered to be impaired when the hearing level is shifted 25 dB or more, averaged over the 500, 1000 and 2000 Hz frequencies (the region most critical in speech perception). The total impairment level is 1.5 times greater than that for speech.

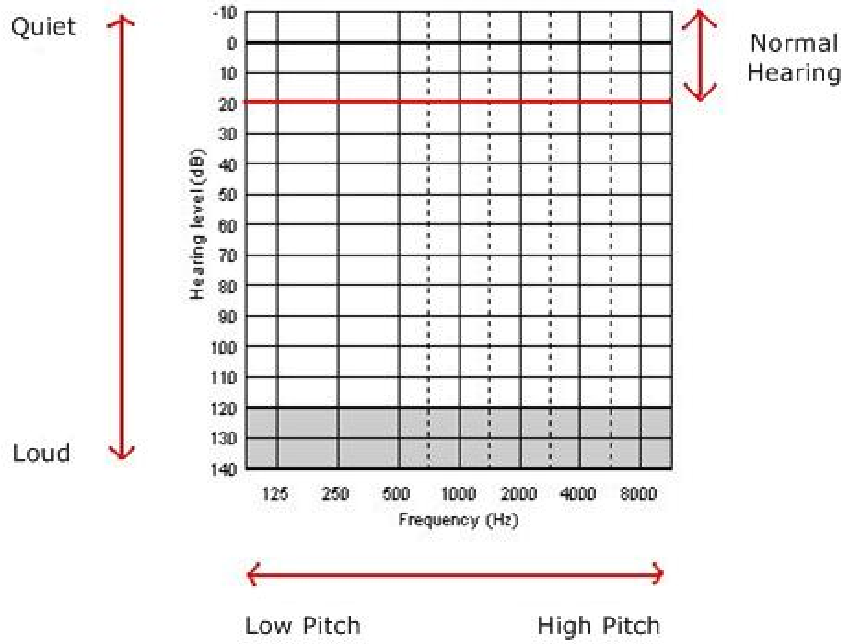
Reference Equivalent Threshold Sound Pressure Level (RETSPL)
The RETSPL values are intended for the calibration of audiometers using pure tones of fixed frequencies at the preferred frequencies in one-third octave steps or pure-tone audiometers with a continuously variable frequency.
In calibration, the sound pressure level at the test point, which corresponds to the listener's threshold, is found. These threshold values are called the reference equivalent threshold sound pressure level (RETSPL). RETSPL are required to calibrate the sound field. The audiometer is set to produce the RETSPL at the test point when the dial reading is zero. Measurements of a subject's thresholds above the RETSPL will be represented using dB HL.

Pure-tone Testing
Pure-tone tests are used to determine hearing sensitivity; the type, degree and configuration of hearing loss. This measure involves the peripheral and central auditory systems. Pure-tone thresholds (PTTs) indicate the softest sound audible to an individual at least 50% of the time. Hearing sensitivity is

Hearing Level:

The results of a pure-tone hearing test are plotted on an audiogram. Hearing is considered good if every tone sounded between 64 and 8,192 Hz is heard at a volume of 20 decibels (dB).

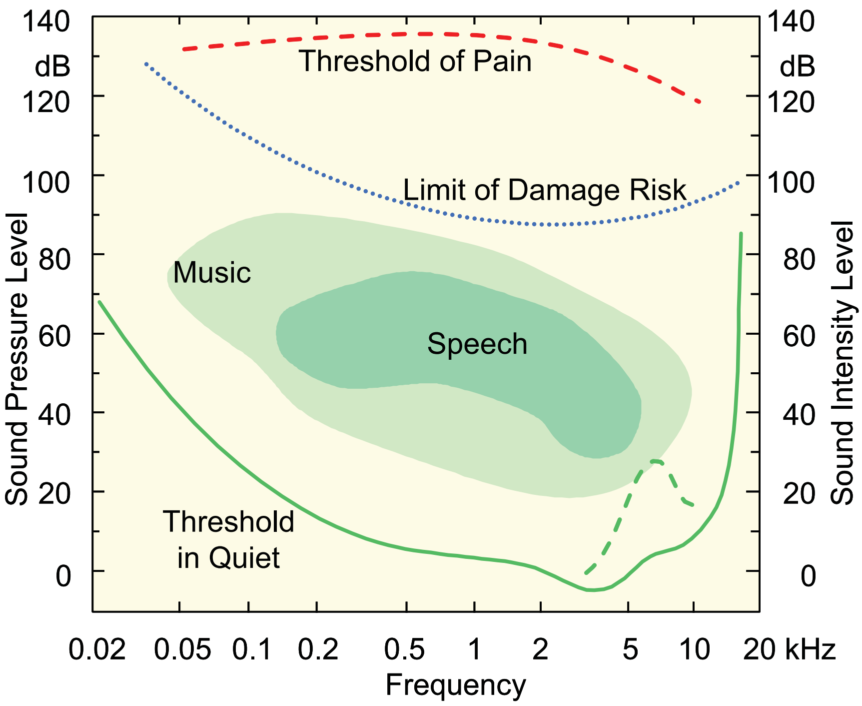
- Normal hearing
  = 0 < 25 dB HL (adults)
  = 0 < 15 dB HL (children)
- Mild hearing loss
  = 25-40 dB HL
- Moderate hearing loss
  = 41-65 dB Hl
- Severe hearing loss
  = 66-90 dB HL
- Profound hearing loss
  = 90+ dB HL



plotted on an audiogram, which is a graph displaying intensity as a function of frequency. The audiogram is a chart of hearing sensitivity with frequency charted on the abscissa and intensity on the ordinate. Intensity is the level of sound power measured in decibels; loudness is the perceptual correlate of intensity.

For threshold testing intensity, decibels are measured in hearing level (HL), which is based on the standardized average of individuals with normal hearing sensitivity. HL is not equivalent to sound pressure level (SPL). A hearing thres-hold level around 20 dB HL is considered to indicate normal hearing.

This display of the auditory field illustrates the limits of the human auditory system. The solid line denotes, as a lower limit, the threshold in quiet for a pure tone to be just audible.



Sound Quality or Timbre

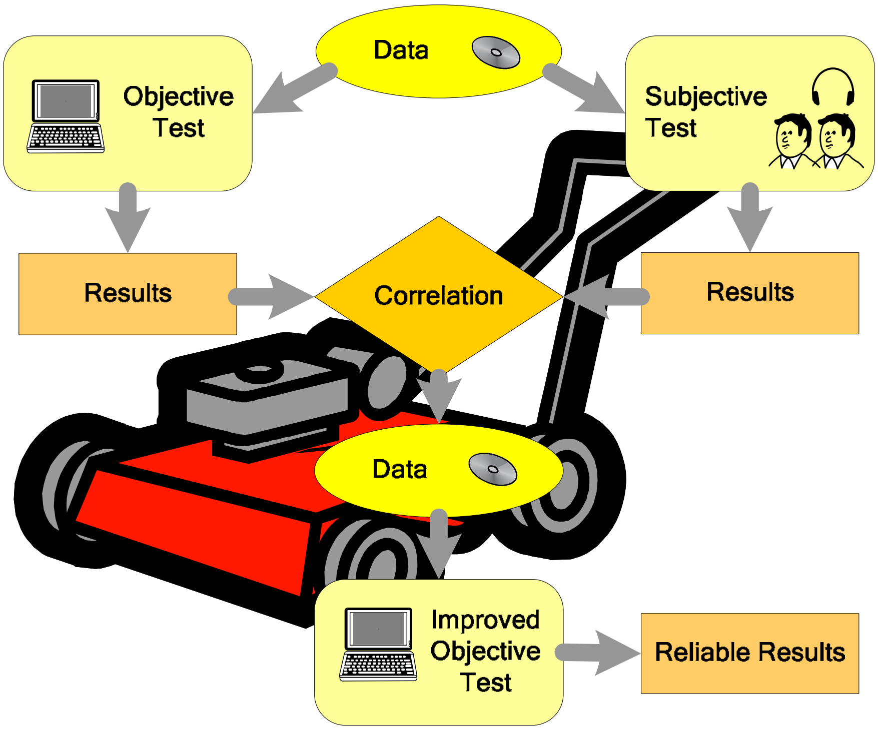
Sounds may be generally characterized by pitch, loudness and quality. Sound quality and timbre are general terms for the distinguishable characteristics of a tone. Sound "quality" or "timbre" describe these characteristics of a sound which allow the ear to distinguish it from other sounds having the same pitch and loudness. Timbre is mainly determined by the harmonic content of a sound and the dynamic characteristics of the sound such as vibrato and the attack-decay envelope of the sound.
Some investigators report that it takes about 60 ms to recognize the timbre of a tone, and that any tone shorter than about 4 ms is perceived as an atonal click. It is suggested that it takes about a 4 dB change in mid or high harmonics to be perceived as a change in timbre, whereas about 10 dB of change in one of the lower harmonics is required.
The sound quality of the noise from a product is of increasing importance when assessing the total quality of the product. For products ranging from cars to hand tools, not only the level but also the quality of the noise it makes is part of what attracts or repels the customer; the right sound can lead to increased sales.
Many factors come into play in the sound quality evaluation process combining objective measurements and subjective evaluations. Traditional

measuring and analysis methods, such as A-weighted sound pressure and FFT analysis, are not enough to analyse product sound. Customer expectations and jury testing are also important factors for determining acceptable sound quality because, in the end, only the human ear can tell the designer whether or not the product has the right sound.
The correlation between the objective and subjective tests is calculated through statistical analysis, and regression analysis is used to determine and calculate the final combination metric.

Sound Quality Parameters
Acoustic environments are evaluated by human hearing, the sound perception of which can be described in psychoacoustic parameters such as pitch, loudness, volume, roughness, sharpness, timbre and fluctuation strength. These parameters are important in the understanding of auditory perception. Typically these parameters are qualitative parameters and therefore subject to manipulation or suggestion.
Sound Quality metrics are the same as Sound Quality parameters, which can reflect most of the psychoacoustic properties of the human perception of sound. There are some standardized metrics, such as Stationary Loudness, Tone to Noise Ratio, Prominence ratio, but most metrics are not standardized. They all have the advantage that they conclude with a single number on the characteristic properties of the sound.

Pitch
Pitch is the physical property of sound which characterizes its frequency of vibration as judged by the listening ear. Pitch is the perceptual correlate of frequency. Frequency is cycles per unit of time. Frequency is measured in hertz, which are cycles per second. Usually frequencies of 250 Hz to 8000 Hz are used in testing because this range represents most of the speech spectrum, although the human ear can detect frequencies from 20 Hz to 20,000 Hz. Some children can detect even higher frequencies.

Loudness
Loudness is the subjective impression of the intensity or magnitude of a sound. It is dependent on frequency, waveform and duration, as well as sound intensity or sound pressure. It is expressed quantitatively in units of sones and phons for sine tones or narrow band noise, and in terms of Perceived Noise Level (PNdB) for broad band environmental sounds.
The loudness level of a sound is measured by making a subjective comparison between the loudness of the sound and that of a pure tone, of single specified frequency that seems equally loud. The Sound Pressure Level of the pure tone in phons is then called the loudness level of the sound.
The phon is a unit related to dB by the psychophysically measured frequency response of the ear. By definition readings in phons and dB at 1 kHz are the same. For all other frequencies, the phon scale is determined by the results of experiments in which volunteers have been asked to adjust the loudness of a signal at a given frequency until they judged its loudness to equal that of a 1 kHz signal. Over much of the frequency range it takes about a threefold increase in sound pressure (a tenfold increase in acoustical energy, or, 10 dB) to produce a doubling of loudness.
The sone is derived from psychophysical measurements which involved volunteers adjusting sounds until they judge them to be twice as loud. This allows one to relate perceived loudness to phons. A sone is defined to be equal to 40 phons. Experimentally it was found that a 10 dB increase in sound level corresponds approximately to a per-



Sound Quality is a parameter that sells a product —a signal that the product operates properly.

Sound Quality Parameters

- Loudness
- Sharpness
- Statistical Loudness and Sharpness Max. / Min.
- Standard Deviation
- Instantaneous Loudness
- Total and Specific Fluctuation Strength
- Total and Specific Roughness
- Tone-to-noise Ratio
- Prominence ratio
- RMS of time and frequency data
- Pleasantness
- Annoyance
- Tonality, Pitch Strength
- Speech Interference Levels (SIL)
- Intelligibility, Articulation Index (AI)
- Speech Transmission Index (STI)
- Kurtosis

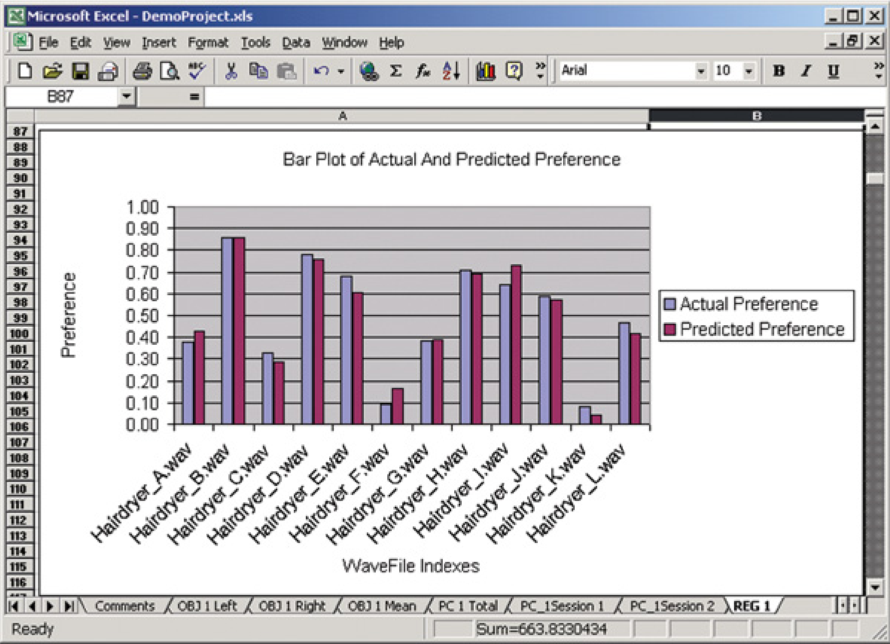
ceived doubling of loudness. A popular way of stating it is that it takes 10 violins to sound twice as loud as one violin.

Equal Loudness Contour
The equal loudness contours are a set of standardized curves for normal hearing of pure tones for human beings. An equal-loudness contour is a measure of sound pressure (dB SPL), over the frequency spectrum, for which a listener perceives a constant loudness when presented with pure steady tones.
The curves are based on psycho-acoustic tests and show how the subjective loudness of a pure tone of given physical sound pressure level varies with frequency. The tests were carried out by presenting the tone to be judged to a large group of people in the age group 18 to 25 years. During the tests, these people adjusted a 1000 Hz reference until it appeared to have the same loudness as the tone being presented. 1000 Hz is thus the reference for all loudness measurements.
All contours of equal loudness level, expressed in Phons, have the same numerical value as the sound pressure level at 1000 Hz, i.e. the curve going through 80 dB at 1000 Hz is denoted 80 Phon curve. The 0 Phon curve is also called the “Threshold of Hearing” and the 120 Phon curve is called the “Threshold of Pain”. The definitive curves are defined in the international standard ISO 226:2003 which is based on a review of several modern determinations made in various countries.

The basic dynamic indications in music are p for piano, meaning "soft", and f for forte, meaning "loud" or "strong".

Dynamic range	Phons	Sones
	120	256
	110	128
fff	100	64
ff	90	32
f	80	16
---	70	8
p	60	4
pp	50	2
ppp	40	1
	32	1/2
	25	1/4
	19	1/8
	14	1/16
	11	1/32
	9	1/64

Zwicker Loudness
Zwicker Loudness is the most important tool for objectively determining sound quality parameters or metrics. It attempts to understand how the human ear experiences sounds by properly weighting the different parts of the sound signal.



Sound Quality measurements on a hairdryer.

An objective method developed by Prof. Dr. E. Zwicker may be applied to calculate a real-time estimate for the loudness of sound as perceived by the human ear. It has primarily been used for steady state conditions, but with increasing computer power, it is becoming more common to be used for dynamic conditions as well. The computation of Zwicker loudness *N* (in sones) uses a fairly complex graphical method based on 1/3-octave band sound pressure levels. The complexity arises because loudness perception is a function of sound pressure level, frequency, and the spectral shape of the sound. The method, based on the use of the 25 1/3 octave bands between 20Hz and 12500Hz, makes allowance for masking. The technique also weights the different 1/3 octave bands depending on their frequency and level. In a similar way, the bands are assigned different widths, dependant on the relative annoyance of the bands as opposed to the 'equal loudness' curves used for the A, B and C weightings. Zwicker's loudness model has the following stages:

1. A fixed filter representing transfer through the outer and middle ear;
2. Calculation of an excitation pattern from the physical spectrum;
3. Transformation of the excitation pattern to a specific loudness pattern.

Sharpness
Sharpness is a measure of the excessive high-frequency content in a signal. For example, white noise has more high-frequency level than pink noise and a higher sharpness value. It is more unpleasant to listen to.

Fluctuation Strength
Fluctuation Strength is a measure of the low-frequency (below 20 Hz) amplitude and frequency modulation of sound. It is perceived as changes in the frequency and volume of the sound with time. Fluctuating signals of this type sound louder, and more annoying, than a steady signal of the same RMS magnitude. The effect is most noticeable when the modulation frequency is around 4 Hz.

Roughness
Roughness is a measure of the modulation amplitude and frequency modulation of a sound where the modulation is in the range from 15 to 300 Hz. Maximum roughness occurs around 70 Hz

and gives the unpleasant sensation of a stationary but rough sound. Above this frequency, the time constant of human hearing starts to take effect and reduces the perception of modulation. When determining roughness, the loudness data must be sampled in real-time with a high sampling rate.

Perceived Noise Level (PNdB)
The Perceived Noise Level is a scale developed originally by K.D. Kryter in 1959 to attempt to measure the perceived noisiness of a jet aircraft by observers on the ground. The scale has been adopted by the International Standards Organization for international use. As jet engines were perceived to be noisier than propeller aircraft because of differences in the spectrum of the noise they produce, the method followed a similar approach to loudness summation of complex tones. Using equal loudness tones, Kryter converted the decibel scale into a series of increments, to which he gave the unit of the Noy, which can be converted into PNdB. The equation expressing this relationship is: PNdB = 40 + 10 log2 (noy).

Masking
Masking describes the amount or the process by which the threshold of audibility for one sound is raised by the presence of another (masking) sound. Human beings are rarely exposed to just an isolated sound. The relevant sound normally occurs with several others, usually referred to as background noise. In some situations an otherwise clearly audible sound can be masked by another sound. For example, conversation at a bus stop can be completely impossible if a loud bus is driving past. This phenomenon is called masking. A weaker sound is masked if it is made inaudible in the presence of a louder sound. The masking phenomenon occurs because any loud sound will distort the Absolute Threshold of Hearing, making quieter, otherwise perceptible sounds inaudible.
If two sounds occur simultaneously and one is masked by the other, this is referred to as simultaneous masking. Simultaneous masking is also sometimes called frequency masking. The tonality of a sound partially determines its ability to mask other sounds. A sinusoidal masker, for example, requires a higher intensity to mask a noise-like maskee than a loud noise-like masker does to mask a sinusoid. Computer models which calculate the masking caused by sounds must therefore classify their individual spectral peaks according to their tonality.
Similarly, a weak sound emitted soon after the end of a louder sound is masked by the louder sound. Even a weak sound just before a louder sound can be masked by the louder sound. These two effects are called forward and backward temporal masking, respectively.
The effect of auditory masking is used in Sound masking systems. These are audio systems that broadcast white noise for the purpose of hiding an unwanted sound. The unwanted noise may be intermittent sounds from machinery, people or other sources. Usually, this sound is filtered to provide the best effect of hiding the unwanted noise.

Listening / Subjective Audio
A basic ability to discriminate between different sounds is useful to sound professionals, to recognize a difference, and to be able to identify various types of perceived differences, such as differences in pitch, loudness and timbre. This includes the ability to correlate the auditory difference with the physical properties of sounds and the numerous technical terms expressing acoustic features, e.g. sound pressure level, frequency, and spectrum. Auditory differences should be expressed in appropriate technical terms. Training technical listening may improve the professional sound sensitivity and understanding of the relationship between acoustic properties and auditory impression.
Subjective audio is the evaluation of reproduced sound quality by the ear. It is based on the idea that, since audio equipment is made to be listened to, what it sounds like is more important than how it measures. A component, and an audio system as a whole, should reproduce what is fed into it, without adding anything to it or subtracting anything from it. Measurements of things such as harmonic distortion, frequency

Subjective listening tests may to some extent be replaced by objective measurements to determine well-defined sound quality parameters.

Examples of Listening Terms:

Airy:
Elicits an image of expansive openness and describes treble extension seemingly without limit.

Coloured:
A visual analog describing a characteristic that adds something not in the original sound.

Boomy:
An onomatopoeia referring to an overload of lower end frequencies.

Bright:
Usually refers to too much upper frequency energy.

Grainy:
The sonic analog of the grain seen in photos describing a sort of "grittiness" added to the sound.

Muddy:
A sound that is poorly defined, sloppy or vague. For example, a "muddy" bass is often boomy with all the notes tending to run together.

Warm:
The opposite of cool or cold and in terms of frequency generally considered the range from approximately 150 Hz-400 Hz. A system with the "proper" warmth will sound natural within this range.

response, and power output may reveal imperfections of a product, but there are no generally accepted guidelines for equating the measurements with the way they affect the reproduced sound. Subjective reviewing simply attempt to describe what is heard, what the reproducing system sounds like.
Most subjective audio terms that are not drawn from everyday usage fall into three categories:

1. Onomatopoeia: words that sound like what they describe
2. Imagery: words that evoke a mental image
3. Sensories: words that relate things to more familiar things often seen or touched

Musicians have for a long time been familiar with terms like "mellow," "strident," "rich," and "euphonic," but the advent of reproduced music has introduced sonic qualities for which new descriptive terms were needed.

Speech Intelligibility

In many daily life situations it is important to understand what is being said, for example over a loudspeaker system, and to be able to react to acoustic signals of different kinds.
Speech intelligibility in everyday conditions is influenced by speech level, speech pronunciation, talker to listener distance, sound level and other characteristics of the interfering noise, hearing acuity and the level of attention. Indoors, speech communication is also affected by the reverberation characteristics of the room.
For full sentence intelligibility in listeners with normal hearing, the signal to noise ratio - the difference between the speech level and the sound level of the interfering noise - should be at least 15 dB(A).
Perceived speech quality is most directly measured by subjective listening tests. Currently the most accurate method for evaluating speech quality is through subjective listening tests. These tests are often slow and expensive, and numerous attempts have been made to supplement them with objective estimators of perceived speech quality. These attempts have found some success, primarily in analog and higher-rate, error-free digital environments where speech waveforms are preserved or nearly preserved. In the straightforward cases, it is possible to estimate speech intelligibility from physical measurements and to dispense with the need for listeners and talkers.
Speech Intelligibility is usually expressed as a percentage of words, sentences or phonemes (speech sounds making up words) correctly identified by a listener or group of listeners when spoken by a talker or a number of talkers. It is an important measure of the effectiveness or adequacy of a communication system or of the ability of people to communicate in noisy environments.

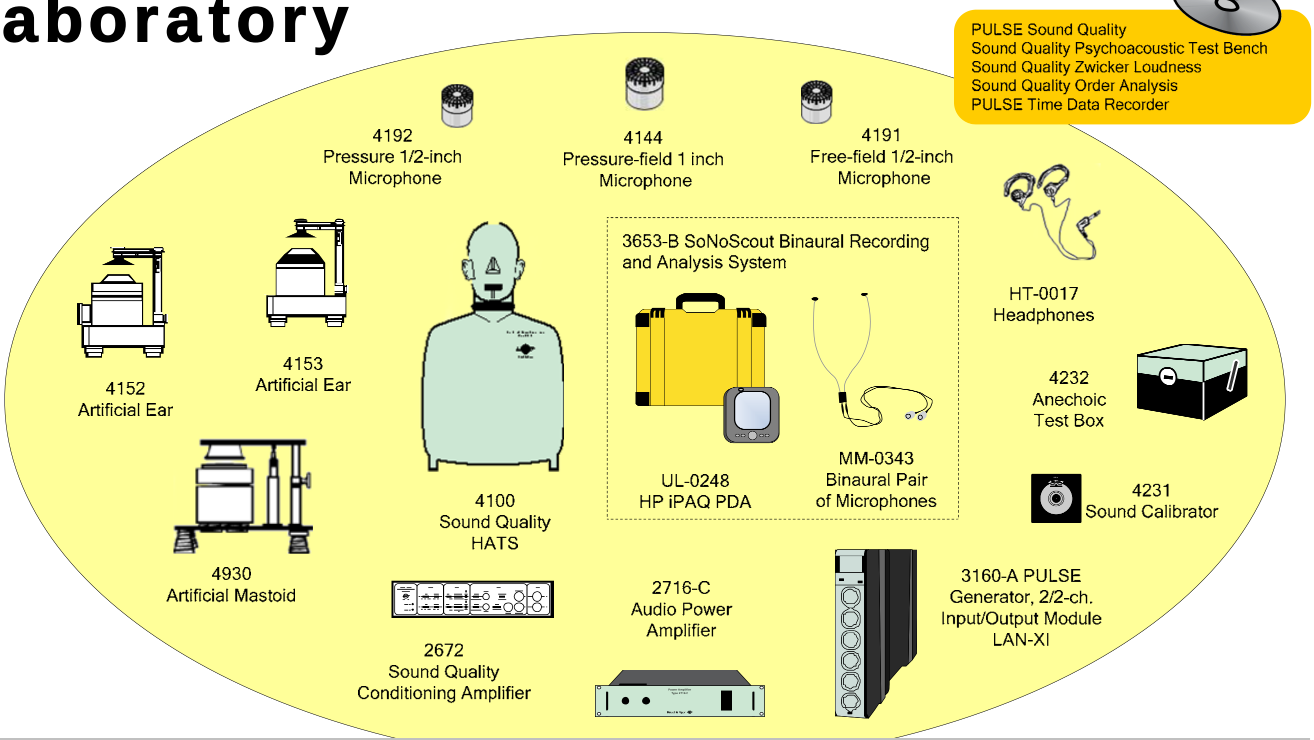
Artificial Head technology is a useful tool as an objective recording system analogous to human hearing. Backed up by listening tests, recordings are able to provide aurally accurate reproductions of acoustic environments.

Speech intelligibility is adversely affected by noise. Most of the acoustical energy of speech is in the frequency range of 100-6000 Hz, with the most important cue-bearing energy being between 300 and 3000 Hz.
Speech interference is basically a masking process, in which simultaneous interfering noise renders speech incapable of being understood. Environmental noise may also mask other acoustical signals that are important for daily life, such as door bells, telephone signals, warning signals and music.
Speech measurements can be carried out through an artificial mouth-directional loudspeaker sound source or through direct injection into a sound system, taking into account the impact of background noise.
International Electrotechnical Commission (IEC) and International Standards Organization (ISO) standards already incorporate objective methods for evaluating speech intelligibility. Evaluation of speech intelligibility may use any one of several both objective and subjective methods cited in the standards.
Speech Transmission Index (STI) is an objective measure that indicates the quality of the transmission of speech, intelligibility, whose value varies from 0 = completely unintelligible to 1 = perfect intelligibility. On this scale, an STI of at least 0.5 is desirable for most applications. It is used with reference to public address systems as it takes into account the noise from external and internal sources.
Another speech intelligibility parameter is Percentage Loss of Consonants, %ALC. Consonants play a much more significant role in speech intelligibility than vowels. If the consonants are heard clearly, the speech can be understood more easily. Since %ALC expresses loss of consonant definition, lower values are associated with greater intelligibility.

Features:

- Sound Quality
- Soundscaping
- Audiology
- Audiometer Testing
- Hearing Aid Testing
- Psychoacoustic Testing

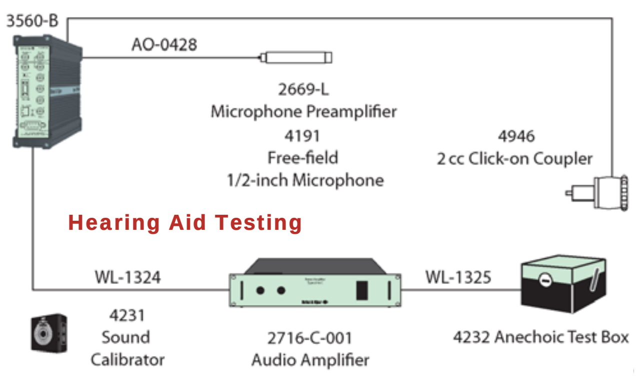
Audiology and Psychoacoustics Laboratory

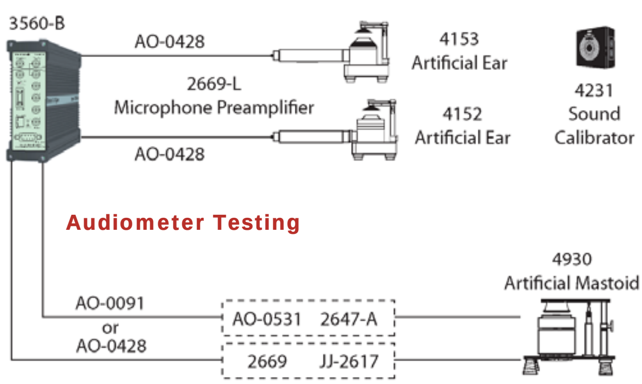


Analyzer and Software
3160-A-022 Generator, 2/2-ch. Input/Output Module LAN-XI
UA-2102-022 Detachable 2 Ch. Lemo + 2 Ch. BNC Connector Panel for LAN-XI Module
7700-N2 PULSE FFT&CPB Analysis, 1-2 Channel, Node-locked License
7708-N2 PULSE Time Data Recorder 1-2 Channel, Node-locked License
7698-N PULSE Sound Quality, Node-locked License
BZ-5265-N PULSE Sound Quality Zwicker Loudness, Node-locked License
BZ-5301-N PULSE Sound Quality Psycho-acoustic Test Bench, Node-locked License
BZ-5277-N PULSE Sound Quality Order Analysis, Node-locked License

Transducers and couplers
4144 1" Pressure- field Microphone, 3Hz to 10KH, 200 V Polarization
4191 1/2" Free-field Microphone, 3Hz to 40 KHz, 200V Polarization
4192 1/2" Pressure-field Microphone, 3Hz to 20 KHz, 200V Polarization
2669-L 1/2" Microphone preamplifier, tapered, incl. AO-0419 cable
4152 Artificial Ear / Ear Simulator
4153 Artificial Ear / Ear Simulator
4930 Artificial Mastoid
2647 Charge to Deltatron converter
4946 2CC Click-on Coupler

Additional items
4100 Sound Quality Head &Torso Simulator, includes 2669L preamplifiers with CIC
4232 Anechoic Test Box
3653-B SoNoScout Binaural recording and analysis system
JJ-2617 Input adaptor,1/2"mic.to microdot
HT-0017 Headphones
4231 Sound Calibrator Class 1 and LS, 94 and 114 dB, 1 kHz
2716-C Audio Power Amplifier, Stereo
AO-0038-D-300 Cable super low-noise,10-32 UNF (M) to 10-32 UNF (M),30m (100ft)
JP-0145 Adaptor BNC (M) to 10-32 UNF (F)



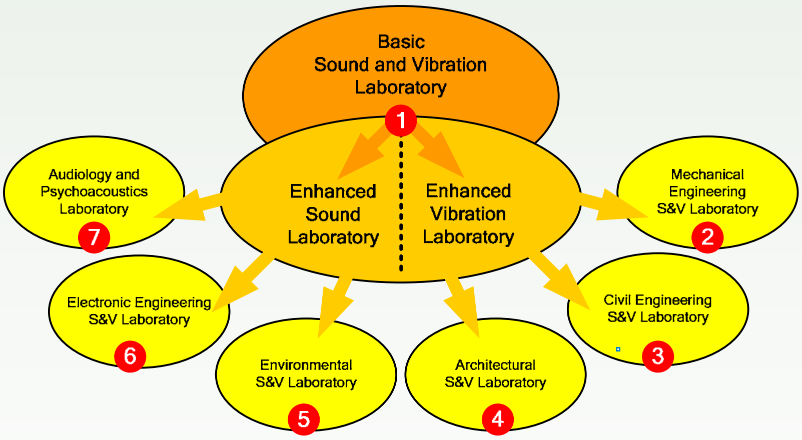


Sound and Vibration in Education

Sound and vibration reach into almost every aspect of everyday life. In every sector of industry, in every part of the scientific community and in all aspects of daily life, people are working with challenges of sound and vibration. Industry, trade and public services demand new solutions, more knowledge and more education.
Effective sound and vibration solutions in modern society require engineering education providing a fundamental understanding of the generation, transmission and radiation mechanisms associated with sound and vibration: Multi-disciplinary knowledge ranging from applied mathematics and mechanics to sound perception and signal processing.
Apart from an understanding of theories, students of engineering and physics require knowledge of the techniques of testing and measuring used in industry and research laboratories. Measuring and testing that can prove the validity of calculations, simulate practical environments and create models, and allow experiments where calculations are not possible.
In technical colleges and universities, electronic measuring instruments are used in demonstrations, exercises, and student projects. They also provide the teacher with an indispensable tool to demonstrate the validity of theory taught. Measuring equipment is essential to modern education and learning. Appropriate and flexible sound and vibration laboratories are needed. From the basic laboratory to advanced and specialised solutions — Brüel & Kjær is a world leading manufacturer and supplier.

Sound and Vibration Laboratory Packages

From basic laboratory to advanced solutions



The Brüel & Kjær publication series "Sound, Vibration, Education" includes seven documents describing measurements, applications and laboratory packages in different fields of sound and vibration.
Each document describes a particular line in engineering education or a special focus area in sound and vibration and lists the matching set-up of Brüel & Kjær products — the experimental laboratory equipment suitable for these specialised purposes: a laboratory package.

Brüel & Kjær
Incorporating LDS and Lochard

HEADQUARTERS: Brüel & Kjær Sound & Vibration Measurement A/S DK-2850 Nærum Denmark
Telephone: +45 77 41 20 00 Fax: +45 45 80 14 05 www.bksv.com info@bksv.com

Sound Level Meters

Transducers

Analysers

Test and Measurement

Solutions